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INSTRUCTION MANUAL

PLATINUM RESISTANCE THERMOMETER

MODEL PT-2

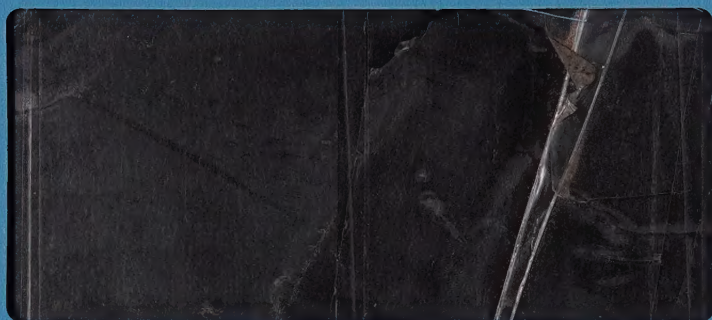
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PRINCETON APPLIED RESEARCH CORPORATION

PRINCETON, NEW JERSEY



INSTRUCTION MANUAL
PLATINUM RESISTANCE THERMOMETER
MODEL PT-2

THIS MANUAL APPLIES SPECIFICALLY TO MODEL PT-2 SERIAL NO. 108

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SECTION I

CHARACTERISTICS

INTRODUCTION

The Model PT-2 Platinum Resistance Thermometer performs rapid, accurate temperature measurements over a wide range of temperatures. Because the function relating the variation of the resistance of Platinum with positive temperatures is quadratic, and because it is possible to construct a variable resistance network which generates an identical function, the Model PT-2 provides temperature measurements accurate to $.01^{\circ}\text{C}$ over the range of 0°C to $+1000^{\circ}\text{C}$ ($.1^{\circ}$ below 0°C).

In essence, the PT-2 compares, in a bridge, the resistance of the Platinum sensor with the equivalent resistance of the function generator network, where the resistance of the function generator depends on the setting of the front panel dials. When the bridge is balanced, these dials directly and clearly indicate the sensor temperature in degrees Celsius. Any bridge unbalance results in a bridge output. This output, following amplification by an automatically stabilized high gain null detector, causes deflection of the variable sensitivity front panel meter, which also indicates directly in temperature (maximum sensitivity is $\pm .01^{\circ}\text{C}$ full scale). The null detector output is also provided at front and rear panel binding posts for external temperature control or temperature deviation recording.

Featuring high accuracy, excellent stability, simple calibration, and the capacity for multiple sensor operation, the Model PT-2 should prove of value in those applications where accurate temperature measurement, or control, is paramount.

CONTROL TEMPERATURE SET:

The temperature at which the controlled "environment" is to be maintained is set with the five front panel decade dials.

CONTROL OUTPUT:

An output voltage proportional to the difference between the set and the measured temperature is available at the output terminals. Maximum output is ± 10 volts at 1 milliampere.

MONITOR:

The front panel meter directly indicates, in degrees Celsius, the difference between the set and the sensor temperatures. Full scale meter indication corresponds to full scale output voltage (± 10 V), unless the range switch is in the "COARSE" position, in which case only polarity correspondence is maintained.

SENSITIVITY:

The front panel Meter Range Switch sets the output sensitivity as follows.

<u>RANGE</u>	<u>SENSITIVITY</u>
0.01°C -----	10 volts/0.01°C
0.1°C -----	10 volts/0.1°C
1.0°C -----	10 volts/°C
10°C -----	1 volt/°C
COARSE -----	Less than 1 volt/°C

SENSOR REQUIREMENTS:

The PAR Model PT-2 Platinum Resistance Thermometer is designed to operate with platinum resistance sensors having the following characteristics:

ICE POINT RESISTANCE:

The sensor resistance at 0°C (R_0) will be 100 ± 1 ohms. A special version of the PT-2 which accepts platinum sensors having an ice point resistance of 25 ohms is also available.

R_0 TRIMMERS:

Two 1/4 watt wirewound resistors (R_C and R_Q) are required with each sensor. Both should have a resistance of $(19.85 \times R_0) - 1888$ ohms, where R_0 is the ice point resistance of the sensor. Neither resistor should have a temperature coefficient greater than ± 20 ppm/°C. The tolerance of R_Q is plus and minus one percent and of R_C , plus or minus ten percent.

LEAD RESISTANCE:

A built in lead resistance compensating network obviates the need for recalibrating a sensor to use it with different length leads. The maximum allowable lead length is determined by the lead resistance, which should not exceed five ohms for each lead (500 feet of #20 AWG copper wire has a resistance of five ohms). Individual leads should be of equal resistance and shielded.

TEMPERATURE COEFFICIENTS:

The equation which describes the variation of the resistance of platinum with positive temperatures is:

$$R_{pt} = R_0 (1 + AT - BT^2)$$

where R_{pt} is the resistance in ohms, R_0 is the ice point resistance, T is the temperature in degrees Celsius, and A and B are coefficients dependent on the individual sample of platinum. Probes suitable for use with the PT-2 must have A and B coefficients which fall within the following limits.

$$A = (3.970 \pm 0.019) \times 10^{-3}$$

$$B = (5.823 \pm 0.108) \times 10^{-7}$$

Should these coefficients not be known for a particular probe, they can be determined by following the procedure outlined under "SENSOR CALIBRATION", page IV-1. If a particular probe is specified in terms of the Callendar - Van Dusen equation, which is:

$$R_{pt} = R_0 + R_0 \alpha \left[T - \delta \left(\frac{T}{100} - 1 \right) \left(\frac{T}{100} \right) - \beta \left(\frac{T}{100} - 1 \right) \left(\frac{T}{100} \right)^3 \right]$$

the A and B coefficients can be determined from the following relationships.

$$A = \alpha + \frac{\alpha \delta}{100} \qquad B = \alpha \delta \times 10^{-4}$$

Note that no effort is made to track the Callendar - Van Dusen equation for negative temperatures. The PT-2 generates a linear function below 0°C and the data from the correction table must be supplied to obtain the specified accuracy.

SUMMARY:

Any four-terminal platinum resistance temperature sensor which meets these specifications may be used with the Model PT-2 Platinum Resistance Thermometer. The usable range and accuracy of the temperature monitoring system will be determined by the range and stability of the temperature sensor used. In general, accuracy is inversely proportional to the range over which the sensor is operating.

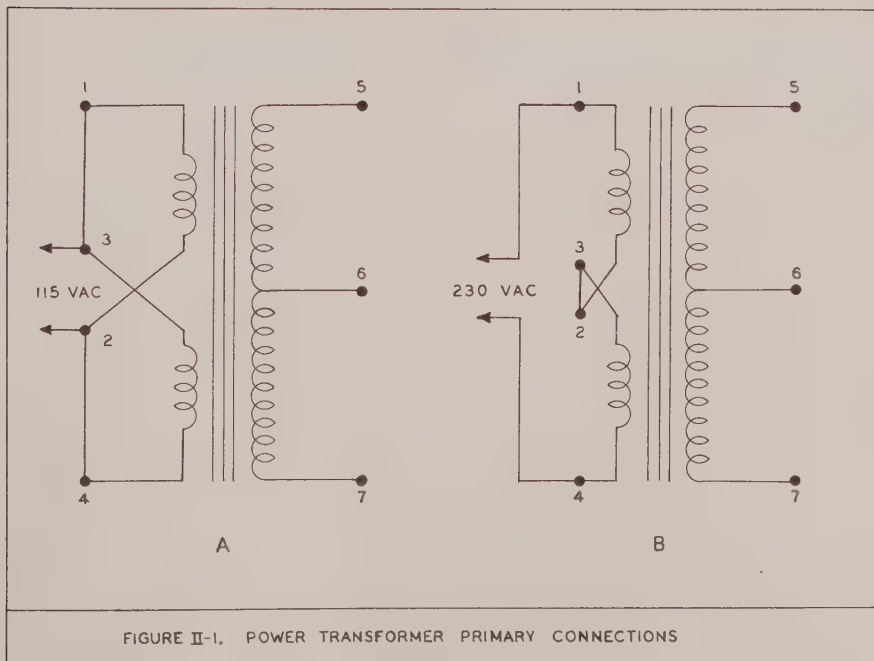
SECTION II
PRELIMINARY INSTRUCTIONS

POWER REQUIREMENTS:

The PT-2 operates from either 105-125 V or 210-250 V AC, 50 or 60 Hz, and consumes approximately 25 watts. It is normally shipped wired for 105-125 volt operation. If shipped wired for 210-250 volt operation, the plug end of the line cord will bear an appropriately marked tag.

Figure II-1 (A and B) indicates the power transformer primary connections for both 115 and 230 volt operation. To change from 115 volt to 230 volt operation, or vice versa, change the power transformer primary connections according to the following procedure.

1. Turn the PT-2 upside down.
2. Remove the bottom cover by removing the seven screws which secure it to the chassis.
3. Locate the primary winding connections of the power transformer.
4. Refer to Figure II-1 and rewire the primary connections as necessary.



If the change is one of both line voltage and line frequency (the usual case), it will be necessary to modify the line voltage rejection filter as well, following the procedure under "LINE FREQUENCY FILTER", page VI-3.

FUSING:

The line fuse located at the rear panel should be as specified below.

<u>LINE VOLTAGE</u>	<u>FUSE TYPE</u>
105-125 VAC -----	3/8 A, Slo-Blo
210-250 VAC -----	2/10 A, Slo-Blo

The voltage rating of the fuse must be at least that of the line voltage.

COOLING:

The Model PT-2 depends on the free circulation of air through its ventilation openings to prevent excessive temperature rise. Consequently, these openings must not be obstructed, as might occur if other equipment were placed on top of or around the PT-2.

WARM-UP:

Because of the thermal stability requirements of the bridge, a warm-up time of one-half hour is recommended if the instrument is to achieve the specified accuracy.

CONNECTING THE SENSOR AND TRIMMERS:

Connect the sensor terminals and the R_O Trimmer Resistors (see " R_O TRIMMERS", page I-3) to the rear panel binding posts as follows.

1. Connect the terminals leading to one end of the sensor to the two binding posts marked "BLACK" and "WHITE" respectively.
2. Connect the terminals leading to the other end of the sensor to the binding posts marked "RED" and "GREEN".
3. Secure the two trimming resistors, R_Q and R_C , to the binding posts identified by the same symbols.

Be sure all connections are tight to minimize contact resistance.

SECTION III

OPERATING INSTRUCTIONS

INTRODUCTION:

The PAR Model PT-2 Platinum Resistance Thermometer basically consists of a manually operated analog computer which simulates the platinum resistance versus positive temperature function at any temperature between 0°C and +1000°C, and presents a direct reading in degrees Celsius of the sensor temperature. Accurate readings below 0°C are obtained by applying a correction table to the indicated temperature. Thus, the instrument is capable of tracking the sensor over a range of -192°C to +1000°C. The range over which one can use the instrument, however, depends on the range of the sensor.

TEMPERATURE MEASUREMENT ABOVE 0°C:

The Model PT-2 is designed to measure as well as control temperatures in the range of -192°C to +1000°C. When the bridge is balanced, the five front panel decade dials directly indicate the temperature of the sensor. A procedure suitable for measuring positive temperatures follows.

1. Set the Polarity Switch to "+".
2. Set the Range Switch to "COARSE".
3. Adjust the front panel dials, beginning with the most significant digit, until the closest-to-zero meter indication is obtained. NOTE: No amount of unbalance will damage the meter.
4. Set the Range Switch to "10°".
5. Adjust the dials to obtain the closest-to-zero meter indication.
6. Set the Range Switch to "1°".
7. Repeat step "5".
8. Set the Range Switch to ".1°".
9. Repeat step "5".
10. Set the Range Switch to ".01°".
11. Repeat step "5".
12. Take the reading, including the meter indication for maximum resolution. NOTE: Full scale on the meter corresponds to the selected range.

Should it occur that the temperature drift during the measuring time exceeds $.01^{\circ}$, it will be necessary to leave the Range Switch in one of the less sensitive positions.

When the Range Switch is in the $.01^{\circ}$ position, an occasional shift of the meter indication may be observed. These slight changes in indication, which occur approximately every 30 seconds, are due to periodic stabilization of the null detector circuit against any thermally generated emf anywhere in the measuring circuit. The thermal emf stabilization cycle is also initiated every time the Range Switch setting is changed. As a result, when changing ranges, the switch should be allowed to dwell in each position for approximately two seconds so that the stabilization sequence, once initiated, will go through a complete cycle.

Under certain conditions determined by the time constant of the sensor and the thermal conductivity of the medium surrounding the sensor, one may observe a slight drift between stabilization cycles. This apparent instability is due to self heating of the temperature sensor due to the excitation current. During each stabilization cycle, the excitation current is interrupted, the sensor temperature drops slightly, and the temperature indicated immediately after the stabilization cycle will be slightly lower than that indicated just prior to it. At the end of the stabilization cycle, excitation current is restored, and the indicated temperature begins rising again.

The bridge excitation of the PT-2 will result in a power dissipation of approximately 10^{-3} watts in the platinum sensor. Whether or not one should "allow" for self heating of the sensor depends on the measurement accuracy desired, and, of course, on whether or not the self heating error is significant compared to the accuracy of the probe and of the instrument. Usually, the self heating effect does not exceed a few millidegrees. By taking the measurement immediately after stabilization when the sensor is "coolest", its effect may frequently be neglected. However, in those cases where the thermal coupling between the sensor and the sample is poor, or where the thermal capacity of the sample is small and the thermal resistance to the external world large, the self heating effect can be significant and must be allowed for. Refer to the specifications provided by the sensor manufacturer for the amount of temperature rise which results from this amount of power under the conditions of thermal transfer of the measurement being made.

TEMPERATURE MEASUREMENT BELOW 0°C :

Except that the indicated temperature must be "corrected" to obtain an accurate reading, the procedure for measuring temperatures below 0°C is the same as that outlined for measuring positive temperatures. To measure negative temperatures, proceed as follows after setting the Polarity Switch to "-".

1. Balance the bridge by carrying out steps "2" through "11" of the directions for measuring positive temperatures.
2. Refer to the correction table, located on the back of the calibration dials cover plate (front panel), and determine between which two horizontally adjacent blocks the indicated temperature falls.

3. Note the corresponding correction. NOTE: Correction degrees are located in the extreme left and right columns, and correction tenths of a degree are indicated in the top horizontal row.
4. Subtract this correction from the indicated temperature to determine the true temperature. To avoid any possible error in algebraic sign when applying the correction, note that the temperature indicated at balance is always lower (colder) than the true or sensor temperature.

Table III-1, a duplicate of the table located on the back of the calibration dial cover, and an example are provided for further clarification of the negative temperature measurement procedure.

	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	
0	000.0	016.0	029.2	038.2	045.5	051.7	057.2	062.2	066.9	071.1	0
1	075.1	078.9	082.5	085.9	089.2	092.4	095.4	098.3	101.0	103.8	1
2	106.4	109.0	111.4	113.8	116.2	118.5	120.7	122.9	125.0	127.1	2
3	129.2	131.2	133.1	135.0	136.9	138.8	140.6	142.4	144.2	145.9	3
4	147.6	149.3	150.9	152.5	154.2	155.7	157.3	158.8	160.4	161.8	4
5	163.2	164.8	166.2	167.6	169.1	170.5	171.8	173.2	174.5	175.9	5
6	177.2	178.5	179.8	181.0	182.3	183.5	184.8	186.0	187.2	188.4	6
7	189.6	190.8	192.0	193.1	194.3	195.5	196.7	197.9	199.0	200.2	7
Table III-1. CORRECTION TABLE FOR TEMPERATURES BELOW ZERO											

EXAMPLE:

1. At balance the dials indicate -185.2°C .
2. Referring to Table III-1, note that -185.2 falls between 184.8 and 186.0 , and that the corresponding correction is 6.6 degrees.
3. Subtracting the correction from the indicated temperature yields the true temperature, which is -178.6°C .

It might be pointed out that with dial settings below -200°C , it is possible to obtain a "false" balance. Such a balance in no way indicates the temperature of the medium surrounding the sensor. In short, there is no way of extending the range of the PT-2 to measure temperatures lower than -192°C (dial settings lower than -200°). The lower right-hand entry of the correction table, "200.2", is not intended to imply that the lower limit dial setting is -200.2 . The extra two tenths of a degree simply permit more accurate division of the 199.0 to 200.2 interval into proportional parts down to the true limit of -200.00 .

TEMPERATURE CONTROL OPERATION:

An error signal voltage proportional to the difference between the sensor temperature and the front panel dial setting is available at the Output Binding

Posts, one pair of which is located at the front panel. When the sensor temperature is higher than the dial setting, the output is positive with respect to ground. When the sensor temperature is lower than the dial setting, the output is negative. For temperature control operation, the output must be connected to a power amplifier capable of driving the temperature control apparatus.

The control sensitivity and full scale indication of the Temperature Deviation Meter are determined by the setting of the Range Switch. As mentioned under "MONITOR", page I-3, full scale control output (± 10 volts, 1 mA) and full scale meter indication correspond, unless the Range Switch is in the "COARSE" position. In that position, the output sensitivity is somewhat less than one volt per degree, and the meter is nonlinear and very insensitive relative to the other positions of the Range Switch. In the "COARSE" position, the meter is connected directly across the bridge, whereas in the other positions, it is driven by the output of the high gain null detector. As the accuracy of the instrument is severely degraded with the Range Switch in the "COARSE" position, readings should be taken only with the Range Switch in a position other than "COARSE".

Achieving loop stability in closed-loop temperature control systems can be very difficult because of the non-minimum phase shift ("delay line") characteristic which frequently is encountered in the heater-to-thermometer path. The general solution is to insert at the output of the PT-2 a filter which results in an overall loop transmission which meets the Nyquist stability criteria. The problems involved in determining the required filter can be very difficult, and the techniques are beyond the scope of this manual. The reader is referred to any of the standard texts on control and servomechanism theory for a complete treatment of the loop stability problem.

DIFFERENTIAL RECORDING:

An analog record of the difference between the dialed and sensor temperatures can be obtained by driving a chart recorder directly from the Output Binding Posts. The sensitivity of such differential recordings is determined by the setting of the Range Switch and the sensitivity of the recorder.

If the recorder one intends to use is a voltage sensing servo type recorder, with a high input impedance and a ten volts for full scale indication sensitivity range, it can be driven directly from the PT-2 output. Full scale PT-2 output will cause the recorder to indicate full scale. If a 1 mA or more sensitive galvanometric type recorder is used, it will be necessary to insert a series resistor between the PT-2 output and the recorder if full scale PT-2 output is to yield full scale recorder indication.

MULTIPLE PROBE OPERATION:

If one desires to measure or control temperature at a number of different locations, several sensors may be connected to the PT-2 by way of a sensor selector. A Sensor Selector, manually operated, is available from PAR. NOTE: The Sensor Selector must be ordered separately.

When using this selector, the R_Q binding posts should be shorted together with a low resistance jumper because each sensor has its own R_Q trimmer mounted

on the front panel of the Selector. Because of the looser tolerance requirement for R_C , no degradation in accuracy will occur if one connects an average value R_C trimmer across the R_C terminals, providing that the sensors one intends to use all have an R_O value of 100 ± 1 ohms. The four sensor selector leads are to be connected to the rear panel binding posts where normally the sensor leads are connected, and the leads of the various sensors are connected to the front panel terminals of the Sensor Selector.

For all but the most accurate measurements, the PT-2 may be used with multiple probes without the need for recalibrating. The magnitude of the small resulting error will depend on the variation of the characteristics of the individual probes. Should the full accuracy of the instrument be required, reset the values of the "Q", "1/A", and "A/B" calibration adjustments, as appropriate, each time a different probe is selected.

SECTION IV

CALIBRATION

SENSOR CALIBRATION:

Calibration of the sensor consists of adjusting the constants of the reference function generator in the instrument to match the parameters of the sensor. The three calibration controls provided for this purpose, "1/A", "A/B", and "Q", are located under a cover in the lower right-hand corner of the front panel. Also located there is the "OPR./CAL 100°/CAL 10°" Selector Switch used for self calibration of the first two decades of the reference function generator. This switch should be in the "OPR." position during normal operation and during the sensor calibration.

The sensor calibration procedure is based on the following sequence.

1. After setting the 1/A and A/B controls to the middle of their ranges, the Q Control is adjusted for an indication of 000.00°C with the sensor at the ice point.
2. Two widely separated but accurately known temperatures are then measured and the PT-2 indication for these temperatures recorded. The solidification points of Tin (231.913°C) and of Zinc (419.505°C) are suitable references.
3. From the known and indicated values for these two temperatures, the proper settings of the 1/A and A/B Controls are computed.
4. As changing the setting of the 1/A Control affects the Q Control setting, Q must be readjusted, completing the calibration procedure.

In essence, the PT-2 reference arm resistance is made exactly proportional ($\times 25$) to the sensor resistance at three widely separated temperatures. Because the PT-2 by design follows the platinum resistance versus temperature quadratic equation, and because the sensor, by definition, must follow that equation, error free tracking of the PT-2 and the sensor are assured by the three point calibration.

To calibrate the sensor, proceed as follows.

1. Remove the Calibration Dials Cover Plate to gain access to the calibration adjustments.
2. Set the 1/A and A/B adjustments to approximately midrange.
3. Ascertain that the "OPR./CAL 100°/CAL 10°" Switch is in the "OPR." position.
4. Connect the sensor and the R_Q and R_C trimmers to the appropriate binding posts.
5. Turn the instrument on and allow a one hour warm-up time.

6. Place the sensor at the ice point temperature.
7. Allow sufficient time for the sensor to assume the ice point temperature, set the dials to 000.00 (000.01 if the triple point is being used as the reference instead of the ice point), and adjust the Q Control for balance as indicated by the panel meter with the Range Switch in the .01° position. If the range of the Q Control is insufficient to achieve balance, try adjusting 1/A, which changes the range of the Q Control. If this fails, it will be necessary to change the value of the R_C and R_Q trimmers. Should the Q Control setting need to be increased "beyond the stop", increase the value of R_Q and R_C . Should the Q Control setting need to be decreased "beyond the stop", decrease their value.
8. Record the Q Control setting.
9. Place the sensor at the first reference temperature, T_1 , allow sufficient time for the sensor to reach the reference temperature, and adjust the front panel dials for balance as indicated on the panel meter with the Range Switch in the .01° position.
10. Record the indicated temperature as R_1 .
11. Place the sensor at the second reference temperature, T_2 , and proceed as indicated in step nine.
12. Record the temperature indicated as R_2 .
13. Compute the correct settings of 1/A and A/B from the following equations.

$$1/A = 1/A_0 \frac{A_0/B_0 (T_1 - T_2) (T_1 \times T_2)}{R_2 T_1^2 (A_0/B_0 - R_2) - R_1 T_2^2 (A_0/B_0 - R_1)}$$

$$A/B = \frac{R_2 T_1^2 (A_0/B_0 - R_2) - R_1 T_2^2 (A_0/B_0 - R_1)}{R_2 T_1 (A_0/B_0 - R_2) - R_1 T_2 (A_0/B_0 - R_1)}$$

In these equations, $1/A_0$ and A_0/B_0 are the settings of the 1/A and A/B Controls respectively for which the R_1 and R_2 readings were recorded, and T_1 and T_2 are the two reference temperatures.

As an aid in solving these equations using a calculator, the following computation procedure is provided. To insure accuracy when following the procedure, all calculations should be carried out to six significant figures. An additional copy of

this table, perforated for easy removal and copying, is available at the rear of the manual, along with a copy of a table which has been "tailored" for calibration using the solidification points of tin and zinc as temperature references.

COMPUTATION PROCEDURE

<u>Step #</u>	<u>Compute</u>	<u>Result #</u>	<u>Value</u>
1 ----	$\frac{A_0}{B_0} - R_2$ -----	1 ----	_____
2 ----	#1 (result) x T_1 -----	2 ----	_____
3 ----	#2 x R_2 -----	3 ----	_____
4 ----	#3 x T_1 -----	4 ----	_____
5 ----	$\frac{A_0}{B_0} - R_1$ -----	5 ----	_____
6 ----	#5 x T_2 -----	6 ----	_____
7 ----	#6 x R_1 -----	7 ----	_____
8 ----	#7 x T_2 -----	8 ----	_____
9 ----	#8 - #4 -----	9 ----	_____
10 ----	#7 - #3 -----	10 ----	_____
11 ----	$\frac{\#9}{\#10}$ -----	11 ----	_____ = $\frac{A}{B}$
12 ----	$T_2 - T_1$ -----	12 ----	_____
13 ----	#12 x T_2 -----	13 ----	_____
14 ----	#13 x T_1 -----	14 ----	_____
15 ----	#14 x $\frac{A_0}{B_0}$ -----	15 ----	_____
16 ----	#15 x $\frac{1}{A_0}$ -----	16 ----	_____
17 ----	$\frac{\#16}{\#9}$ -----	17 ----	_____ = $\frac{1}{A}$

14. Set the A/B and 1/A Controls to the values calculated in steps 11 and 17 respectively. If the computed values of 1/A and A/B are outside the range of the 1/A and A/B controls, the sensor should not be used with the PT-2. Refer to page I-4 for the allowable limits on A and B for proper operation; values outside these limits indicate that the sensor is not of high quality, or that it has been damaged or contaminated.

15. Reset the Q Control as necessary to re-establish balance at 000.00 when the sensor is at the ice point. This can be done either by repeating steps 6 and 7 (except that this time no re-adjustment of the 1/A Control is permitted), or by calculating the new value Q as follows.

- (a) Calculate A and A_0 from $1/A$ and $1/A_0$, which are known.

- (b) The required change in Q is $(A - A_0) \times 5 \times 10^5$.

- (c) The new setting of Q is $Q_1 + (A - A_0) \times 5 \times 10^5$, where Q_1 is the value of Q recorded in step 8.

If the new value of Q is beyond the range of the Q Control, change the value of R_Q and R_C as indicated in step 7. NOTE: Changes in Q and in the R_Q and R_C trimmers in no way affect the established settings of $1/A$ and A/B .

16. Check the instrument at one or two points well above 0°C . The instrument should now indicate the temperature within the specified accuracy of the sensor.

It may be necessary to recalibrate the probe from time to time as recommended by the manufacturer.

SELF CALIBRATION OF THE BRIDGE:

By using the Self Calibrating Procedure to determine the relative deviations of the resistance values of the first two decades of the reference circuits, one can construct a table of corrections to be applied to all instrument indications above 100°C to obtain an absolute tracking accuracy of $.01^\circ\text{C}$. To perform the self calibration and construct the correction table, allow the PT-2 to warm up for one hour and proceed as follows.

1. Disconnect the sensor from the instrument, but leave the R_Q and R_C trimmer resistors in place.
2. Substitute for the sensor, according to the four lead convention, a variable resistor having a nominal value of 139 ohms and a range of variation of plus or minus two ohms. This resistor should be capable of being varied with a resolution of one milliohm. A low value precision resistor shunted by a large value trimmer will serve this purpose provided that the parallel combination of the two does not drift more than one part-per-million during the calibration procedure.
3. Remove the Calibration Dials Cover plate and set the "OPR./CAL 100° /CAL 10° Switch to the "CAL 100° " position.
4. Set the front panel dials to indicate 099.9(10). Note that this setting is the equivalent of a setting of 100.00.

5. With the Range Switch in the .01° position, adjust the sensor substitution resistor for balance. If the resolution of the resistor doesn't permit an exact balance, record the nearest-to-balance meter indication ($\pm 0.01^\circ$ full scale).
6. Set the front panel dials to 100.00 and record the meter indication.
7. Taking care to observe polarity, subtract the step 6 meter indication from that of step 5. The figure obtained is the correction to be applied when the "100s digit" is "1".
8. Record this "100 degree" correction.
9. Set the front panel dials to 200.00 and record the meter indication.
10. Taking care to observe polarity, subtract the step 9 meter indication from that of step 5.
11. The correction to be applied when the "100s digit" is "2" is the algebraic sum of the difference determined in step 10 and the "100 degree" correction recorded in step 8.
12. Record the "200 degree" correction.
13. Proceed in a manner analogous to that used in determining the "200 degree" correction, to determine the "300 degree" correction, the "400 degree" correction, etc. In each case the obtained correction will be the algebraic sum of: (1), the difference noted, and (2), the algebraic sum of all the previously determined corrections.
14. Construct a table listing all of the corrections determined.
15. Set the "OPR./CAL 100°/CAL 10°" Switch to the "CAL 10°" position.
16. Change the nominal value of the sensor substitution resistor to 104 ohms.
17. Set the front panel dials to indicate 009.9 (10).
18. With the Range Switch in the .01° position, adjust the sensor substitution resistor for balance. If the resolution of the resistor doesn't permit an exact balance, record the nearest-to-balance meter indication ($\pm 0.01^\circ$ full scale).
19. Set the front panel dials to 010.00 and record the meter indication.
20. Proceed in a manner analogous to that used to construct the "100s digit" correction table, to construct a "10s digit" correction table.

The correction to be applied to any given temperature indication is the algebraic sum of the corrections from the two tables. For example, suppose that for a given measurement the dial indication at balance is $+438.91^{\circ}$, and that the "400 degree" correction from the "100s digit" correction table is $+0.006^{\circ}$, while the "30 degree" correction from the "10s digit" correction table is $+0.003^{\circ}$. The algebraic sum of the two corrections is $+0.009^{\circ}$, and the corrected measurement is $+438.92$ degrees. It should be clear that these corrections are to be applied to positive temperatures only.

This calibration should be repeated approximately every six months if an absolute accuracy of 0.01°C is to be maintained. If little change in the correction tables is obtained over several calibration periods, it may be sufficient to recalibrate yearly.

SECTION V

THEORY AND CIRCUIT DESCRIPTION

THE BRIDGE:

Operation of the PAR Model PT-2 Platinum Resistance Thermometer is based on generating a resistance reference function which precisely and accurately follows the variation of the resistance of platinum with temperature.* This parabolic function is produced by varying the resistance of the reference arm of a bridge. The increments of resistance are interpreted in terms of temperature and are so marked on the front panel dials. In balancing the bridge, the sensor resistance at a given temperature is compared with the equivalent resistance of the reference arm, where the accumulated resistance of the reference arm represents the temperature.

Observing the PT-2 Block Diagram, page VIII-2, note that the bridge consists of four "standard" arms plus a fifth lead resistance compensator "arm". One arm of the bridge is simply the sensor. Another is the fixed or "S" arm. The third is the "Q" arm, which consists of the Q adjustment and the series R_Q trimmer resistor. The fourth, or reference arm, consists of two branches, one of which is "fixed", comprising the resistance of the A/B adjustment in series with 56.6 kilohms, and the other of which is the resistance inserted by the front panel decade controls. Both branches are returned to ground through the 1/A Control. Finally, the lead resistance compensator is a variable resistance comprising the series resistance of the R_C trimmer resistor and a resistance which varies with the setting of the front panel dials. When the "Q", "1/A", and "A/B" Controls are properly set through calibration, the function generated by the bridge exactly tracks the resistance versus positive temperature function of the "calibrated" sensor, and at any given temperature the resistance of the reference arm, at balance, will be exactly 25 times that of the sensor.

Besides determining the resistance of the reference arm, the setting of the front panel dials programs the current source which supplies excitation current to the bridge, so as to provide equal increments of output for the same amount of temperature deviation at any temperature above 0°C. This linearization of the output allows the front panel meter to read directly in degrees Celsius over the entire range of the instrument. The relationship between the excitation current and the temperature is:

$$i(T) = (2.96 + 1.8 \times 10^{-3} \times T) \text{mA}$$

where $i(T)$ is the excitation current in milliamperes and T is the temperature above 0°C.

Accurate tracking of the sensor is maintained for positive temperatures only. Below 0°C the reference arm resistance is varied linearly with a slope of 10 ohms/°C, and the negative temperature correction table must be used to

*Patent applied for

obtain the specified accuracy. Also, the excitation current is held constant at approximately three milliamperes over the entire range below 0°C.

Any line frequency signal, which may be picked up either by the sensor or by the bridge circuit itself, is suppressed by a twin-T filter at the bridge output. As a result, accuracy is not degraded in the presence of strong AC fields. Instructions for tuning the filter to the line frequency (50 Hz or 60 Hz) are included in Section VI of this manual.

For good stability with ambient temperature, all resistors and switches are mounted inside an isothermal enclosure made of thick aluminum plates. This also provides a dust cover for the precision components inside. For convenient access to the bridge circuit, the top and bottom covers of the enclosure may be removed, after first removing the chassis covers.

NULL DETECTOR:

The null detector circuit comprises three stages, a chopper amplifier which is connected to the bridge by way of the tuned filter, a periodically stabilized DC amplifier which provides further amplification, and an output memory stage, which filters out stabilization transients. Both amplifiers are located on the Null Detector Circuit Board (see Figure VI-1, page VI-2 for the physical location). Referring to the Null Detector Schematic, page VIII- 4, note that the chopper amplifier consists of two sections, the first comprising transistors Q201 through Q204 and their associated components, and the second transistors Q205 and Q206. The gain of the first section is determined by the ratio of R205 to the resistor selected by the Range Switch. This gain varies between a maximum of 10^3 when the Range Switch is in the .01° position to a minimum of 1 when it is in the 10° and Coarse positions. The gain of the second section is simply the ratio of R238 to the parallel combination of R209 and R210, or 10. As a result, the overall gain of the chopper amplifier varies between ten and 10^4 , depending on the setting of the Range Switch.

A trimpot, R214, sets the gain of the DC amplifier such that a bridge unbalance of .01° yields a null detector output of 10 volts when the Range Switch is in the .01° position. Note that the feedback loop consists of resistors R225, R222, and R221, which together constitute a network from the output of the DC amplifier to the summing point. The ratio of the "effective" resistance of this network to the resistance of R214, R213, and the source resistance (demodulator) determines the DC amplifier gain. An additional factor of two gain is provided by the demodulator transformer. Because an unbalance of .01° yields a bridge output of approximately 10 microvolts, the gain of the DC amplifier will be approximately 50, and the overall null detector gain will vary from 10^6 to 10^3 (both figures approximate because the bridge output is not exactly 10 microvolts per .01° of unbalance), according to the setting of the Range Switch.

Periodic stabilization is employed in the DC amplifier stage to insure that any null detector output results only from bridge unbalance and not from any thermally generated emf. Initiated approximately every 30 seconds, the stabilization cycle takes approximately 1.5 seconds to complete. The several auxiliary circuits responsible for programming events during the stabilization cycle will be described first, followed by a detailed explanation of the sequence itself.

One of the circuits on the Odds and Ends Board, located directly behind the Null Detector Circuit Board, is the 30 Second Timer. This circuit initiates a stabilization cycle every 30 seconds and each time the setting of the Range Switch is changed. (Other Odds and Ends Board Circuits are the Programmable Current Source, which provides excitation current to the bridge, and the Null Detector Output Stage, which drives the Output Binding Posts and the Temperature Deviation Meter.) The timer, which consists of transistors Q301 through Q303, is basically a Miller Integrator which repetitively and automatically generates 30 second ramps. At the end of each 30 second ramp, the generator resets itself and supplies one trigger pulse to the Pulse Generator Circuit (located on the Relay Driver Board, see Figure VI-1, page VI-2). Referring to the Relay Driver Board Schematic, page VIII-6, note that the Pulse Generator Circuit consists of a series of three timing circuits, which energize three reed-relays in proper sequence. Two of the relays, K301 and K302, which disconnect the Null Detector Output Memory and interrupt the bridge excitation current respectively, are located on the Odds and Ends Board. The third, K201, is located on the Null Detector Board. When energized, this relay shorts the output of the Null Detector DC Amplifier to the input of that amplifier. Because the amplifier is an operational amplifier referenced to ground, the output assumes ground potential for the duration that K201 is energized.

Consider a stabilization cycle in detail. Quiescently (during the thirty seconds of normal operation between stabilization cycles), K302 and K301 are energized; the bridge is receiving excitation current and the panel meter is being driven by the DC Amplifier by way of the Output Memory Stage. At the same time K201 is de-energized, and, as a result, the DC Amplifier is operating with a nominal gain of 50. At the end of the thirty second "normal" operation interval, a stabilization cycle begins (see timing waveforms on the Relay Driver Board Schematic, page VIII-6). K301 and K302 simultaneously de-energize, interrupting bridge excitation current and disconnecting the Output Memory Stage, which then maintains the instrument output at the pre-stabilization level during the stabilization cycle interval. Because the excitation current has been removed, any remaining bridge output is "false", probably resulting from thermal emfs. About 0.6 seconds after K301 and K302 de-energize, K201 energizes, and the output of the DC amplifier goes to zero. Meanwhile, C208 at the input of the DC Amplifier becomes charged to the level of the "false" bridge output. K201 remains energized for about 0.2 seconds. When it de-energizes, the DC Amplifier output remains at zero. Because the input of the amplifier became referenced to the "false" bridge output as a result of C208 being charged to that level, the amplifier will now respond only to deviations from it. One tenth of a second after K201 de-energizes, K302 energizes, restoring excitation current to the bridge. With excitation current restored, the bridge output becomes the algebraic sum of the "false" and deviation-from-balance levels. Because the amplifier is referenced to the "false" level, any amplifier output which occurs is due to the bridge unbalance alone. After another .45 seconds, the Output Stage is reconnected to the DC Amplifier output as K301 energizes, marking completion of the stabilization cycle; any instrument output at that time results from bridge unbalance alone.

A precision mechanical chopper is used as the chopper amplifier modulator/demodulator. It is driven by 82 Hz power from an oscillator located on the

Relay Driver Board. The 82 Hz operating frequency assures maximum line frequency rejection. It should be mentioned that the chopper is built to PAR specifications. Should it fail, the replacement should be obtained from PAR.

Referring to the Relay Driver Board Schematic (page VIII-6), note that the power oscillator consists of two cascaded amplifier stages forced to oscillate by means of two feedback loops. A positive feedback signal derived from a diode clipper appears across the potentiometer, R417, the setting of which determines the output amplitude. The frequency of the oscillation is determined by the setting of R409, which allows tuning of the negative feedback Twin-T over a narrow range. The oscillator output is nominally 20 V rms at 82 Hz.

POWER SUPPLIES:

A bridge rectifier feeding a conventional voltage regulator circuit is the main source of power for the PT-2 circuitry. The ± 24 volt output of the Regulator Circuit Board, located to the left of the bridge enclosure, furnishes power to all circuits except the power oscillator, which uses the unregulated ± 31 V DC available at the bridge rectifier output. Because the regulator circuitry is completely conventional, no detailed description is furnished.

A separate shielded and isolated power supply furnishes bridge excitation power. Located next to the main power transformer is an isolation transformer (T2 on the Chassis Wiring Diagram, page VIII-8), which drives rectifier circuitry on the Odds and Ends Board (page VIII-5). The 75 volt output of this circuit drives the Programmable Constant Current Source, consisting of transistors Q306 through Q308 and their associated components. Note that the circuit consists of two sections, or two separate constant current sources. The current supplied by Q306 is constant. That supplied by Q308, however, depends on the voltage at the base of Q307, which in turn depends on the setting of the front panel decade dials. Adjusting these dials changes the resistance in series with "EXCIT ADJ" and thereby the potential at the base of Q307. As the dial setting is changed, the excitation current supplied to the bridge changes such that the bridge output per unit temperature change is constant over the entire range of the instrument. Because of this linearization of the bridge output, the temperature deviation meter indicates directly in degrees Celsius.

SECTION VI

ADJUSTMENTS

The PT-2 is a stable conservatively designed instrument, and as such, should need no adjusting other than that required to perform the calibration procedures of Section IV. Although long trouble free operation can be expected, gradual component change could eventually degrade the performance, which would necessitate "correcting" the internal adjustments. Periodic routine performance of these adjustments is not necessary.

The location of the adjustments and test points is indicated in Figure VI-1.

POWER SUPPLIES:

To adjust the plus and minus 24 V regulators, monitor the plus and minus 24 V test points and adjust "-24 V ADJ" until both voltages are within one percent of their nominal value.

To adjust the bridge excitation current, proceed as follows.

1. Disconnect the sensor.
2. Connect a 100 ± 1 ohm resistor between the "WHITE" and "GREEN" terminals.
3. Connect a DC milliammeter between the "RED" and "GREEN" terminals.
4. Short the "BLACK" and "WHITE" terminals together.
5. Balance the instrument, and after so doing, vary "BRIDGE EXCIT ADJ" until the milliammeter indicates $3.0 \text{ mA} \pm 5\%$.

It may have been noted that in performing step 5 the indication of the panel meter changed slightly. This "apparent" gain change will be corrected during the Null Detector Adjustments.

NULL DETECTOR:

Before making the Null Detector Adjustments allow the instrument to warm up for one hour.

To set "ZERO ADJ" proceed as follows.

1. Set the Range Switch to 10°.
2. Disconnect that sensor lead which is connected to the "RED" terminal.
3. Vary "ZERO ADJ" until the automatic stabilization cycle returns the panel meter indication to zero.

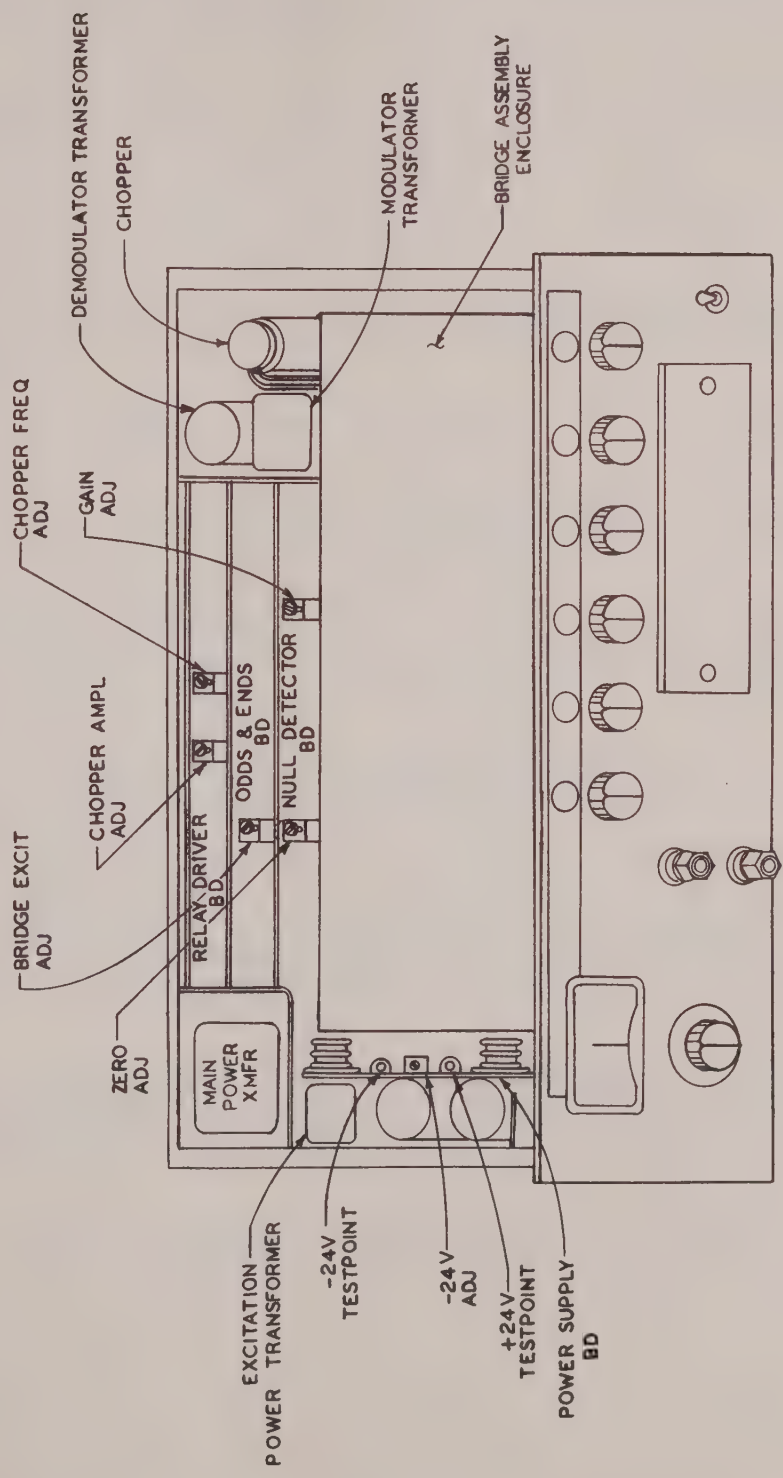


FIGURE VI-1. LOCATION OF ADJUSTMENTS AND TESTPOINTS

To set the "GAIN ADJ" trimpot, proceed as follows.

1. Substitute for the probe a stable wirewound resistor, the value of which can be anywhere between 100 and 200 ohms. The resistor should be connected according to the four lead convention.
2. Balance the instrument with the Range Switch in the .01° position.
3. Set the Range Switch to the 1° position.
4. Change the "dialed" temperature 1°.
5. Observe the resulting deflection of the Temperature Deviation Meter and vary "GAIN ADJ" until full scale deflection is obtained.

Step 5 completes the Null Detector Adjustments.

CHOPPER DRIVER:

Adjust the amplitude and frequency of the Power Oscillator according to the following procedure. Allow a one hour warm-up period.

1. Connect a differential oscilloscope across pins 18 and 20 of the Relay Driver Board.
2. Vary "CHOPPER FREQ ADJ" for a frequency of 82 Hz (a period of 12.2 ms).
3. Vary "CHOPPER AMPL ADJ" for a peak-to-peak amplitude of 56.6 volts (20 volts rms), thereby completing the Chopper Driver Adjustments.

LINE FREQUENCY FILTER:

The line frequency Twin-T filter is located on a printed circuit board mounted inside the bridge assembly. When the top cover of the bridge enclosure is removed, the filter board can be identified by the two trimmer potentiometers mounted on it.

The filter is tuned to either 50 Hz or 60 Hz, whichever is the line frequency. Figure VI-2 shows the location of the frequency determining components and indicates what their value should be for both 50 Hz and 60 Hz tuning. To change the center frequency from 50 Hz to 60 Hz, or vice versa, proceed as follows.

1. Remove the Filter Board from the wall of the Bridge Enclosure and change the values of the components as indicated by Figure VI-2.
2. Return the Board to its normal position.

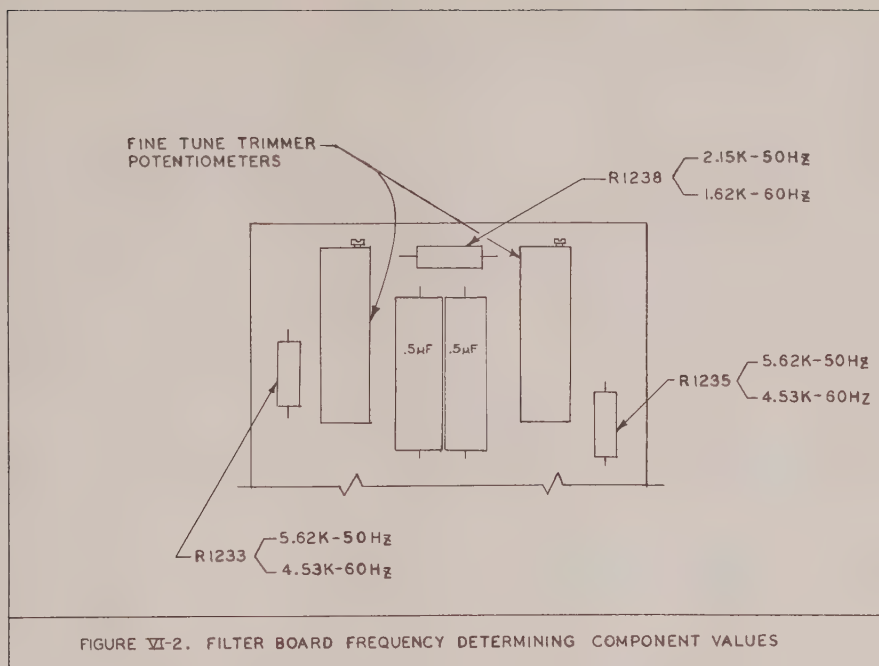


FIGURE VI-2. FILTER BOARD FREQUENCY DETERMINING COMPONENT VALUES

3. Fine tune the filter as follows.

- (a) Unplug the PT-2 line cord.
- (b) Remove the chopper from its socket and disconnect the sensor.
- (c) Set the Range Switch to any position other than Coarse.
NOTE: Leaving the Switch in "COARSE" may result in damage to the Temperature Deviation Meter.
- (d) Connect a sensitive (10 mV) AC VTVM or a differential oscilloscope across pins 2 and 4 of the chopper socket.
- (e) Apply 6.3 V rms at the power line frequency (readily obtained from a filament transformer) across the bridge terminals labeled "RAW BO" and "BO RET" (the two right-hand terminals as seen from outside the bridge enclosure).
- (f) Adjust the filter board trimmer potentiometers for the best null as indicated by the VTVM or oscilloscope, thereby completing tuning of the filter.

SECTION VII

WARRANTY

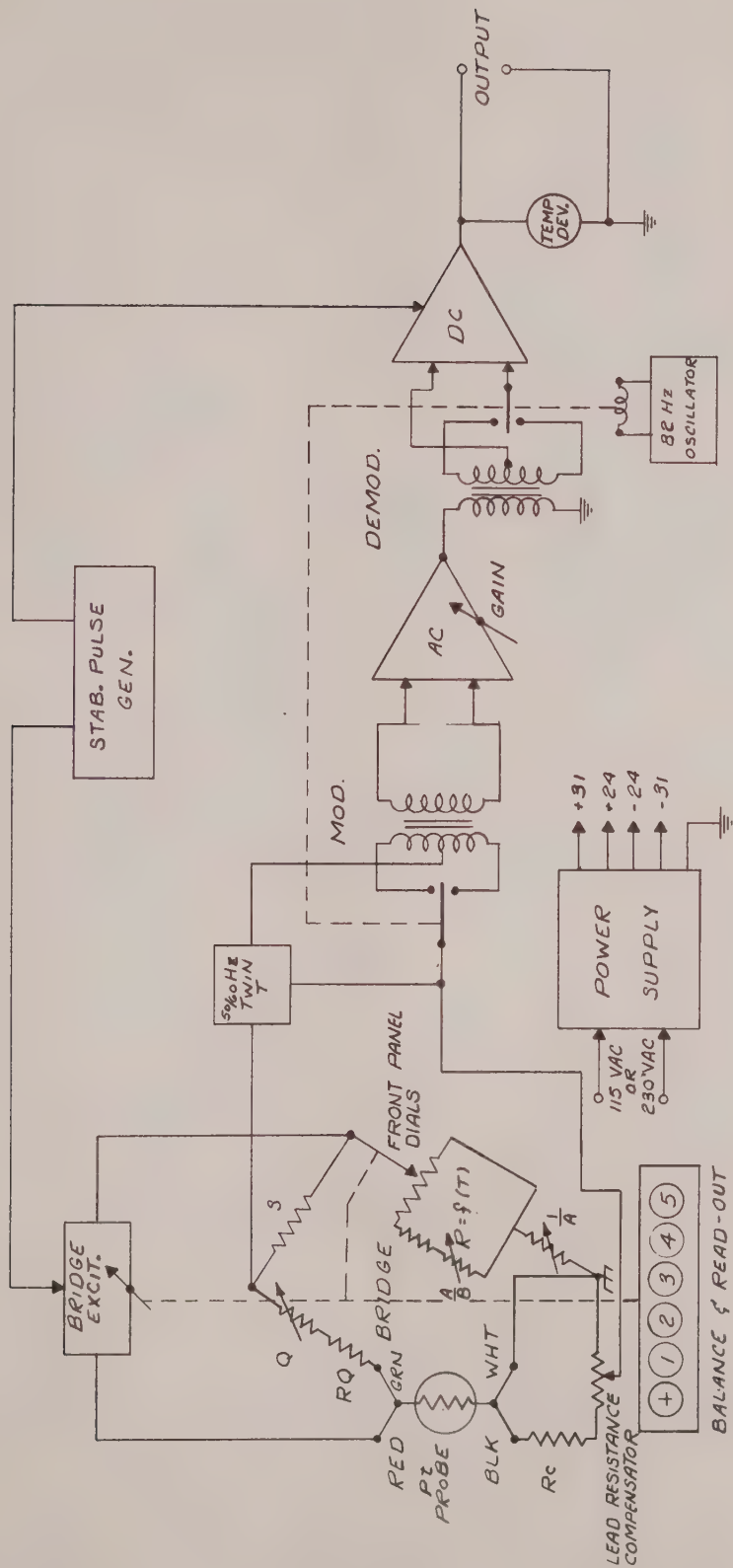
Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this warranty are limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned pre-paid to our factory for that purpose within ONE year of delivery to original purchaser. Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Princeton Applied Research Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control.

Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

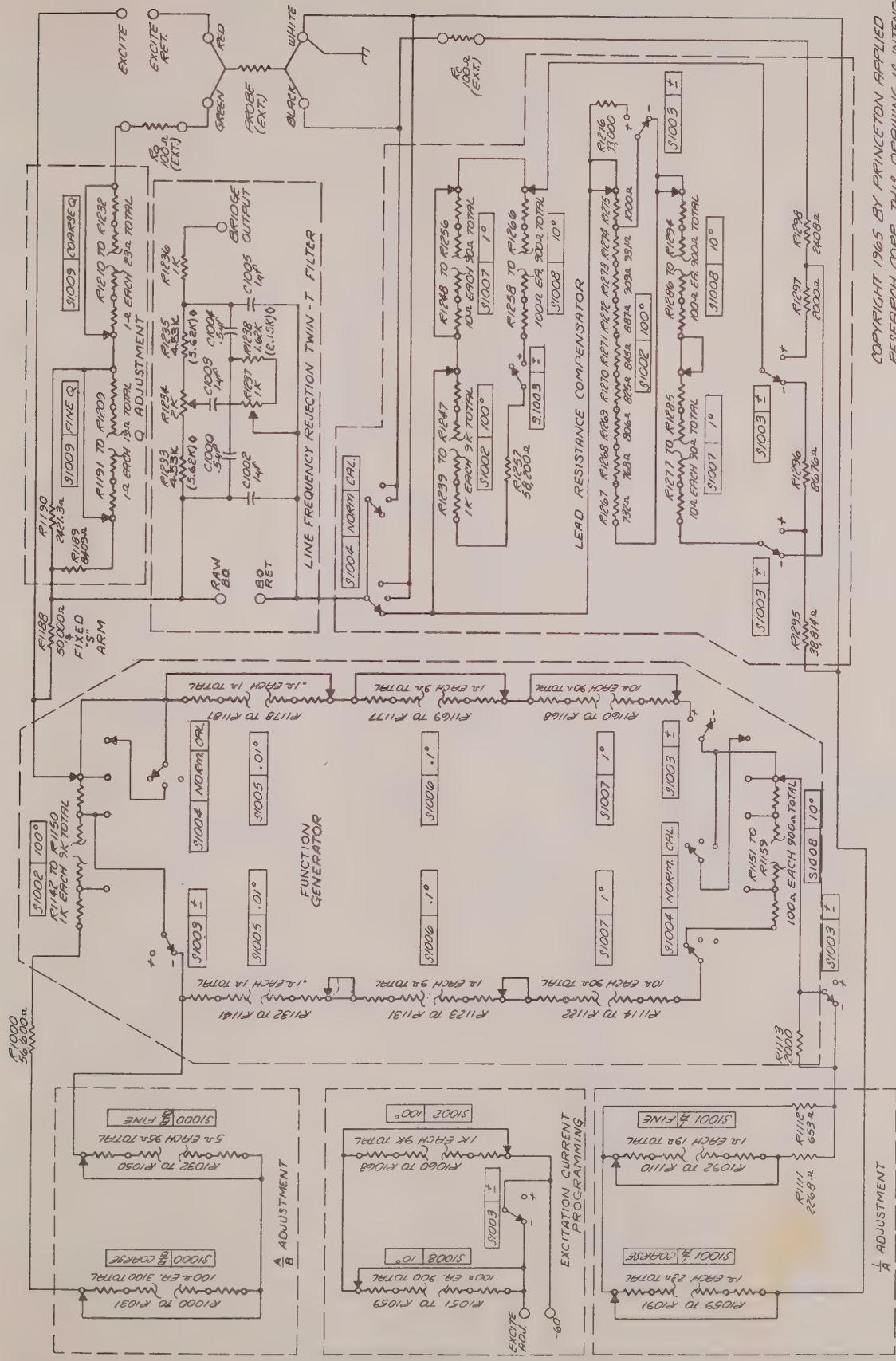
This Warranty is in lieu of, and excludes all other warranties or representations, expressed, implied or statutory, and all other obligations or liabilities of Princeton Applied Research Corporation including special or consequential damages, and no other source is authorized to assume for Princeton Applied Research Corporation any other liability.

SECTION VIII
SCHEMATICS



PT-2 BLOCK DIAGRAM

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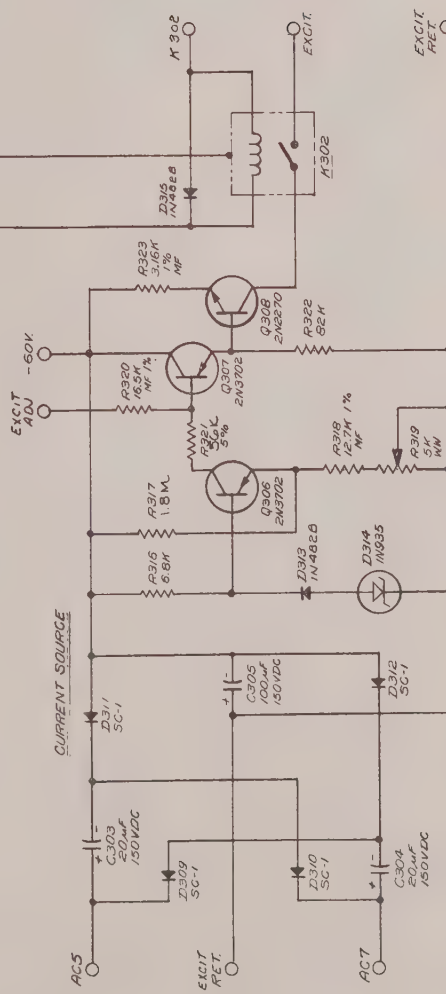
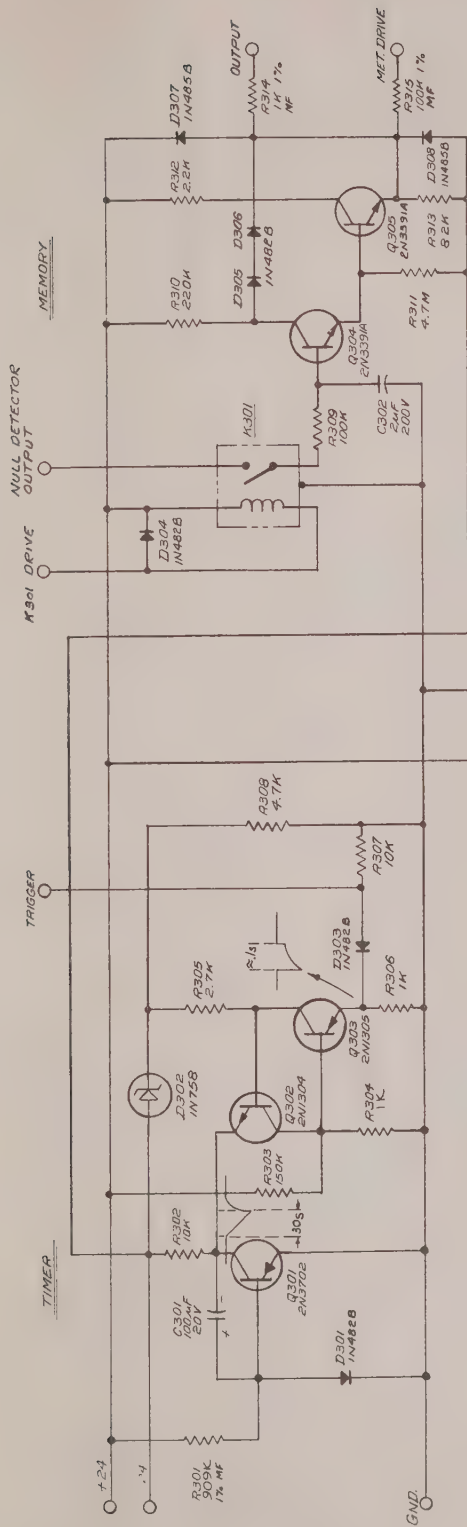


NOTE:
ALL SWITCHES SHOWN IN EXTREME
CLOCK POSITION.
Q - VALUES OF COMPONENTS WHEN
FILTER IS TUNED TO 50 Hz.

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MODEL PT-2

BRIDGE CIRCUIT



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
-27	GND	V24	77K6	150V	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC	150VDC

PIN CONNECTIONS

CIRCUIT BOARD

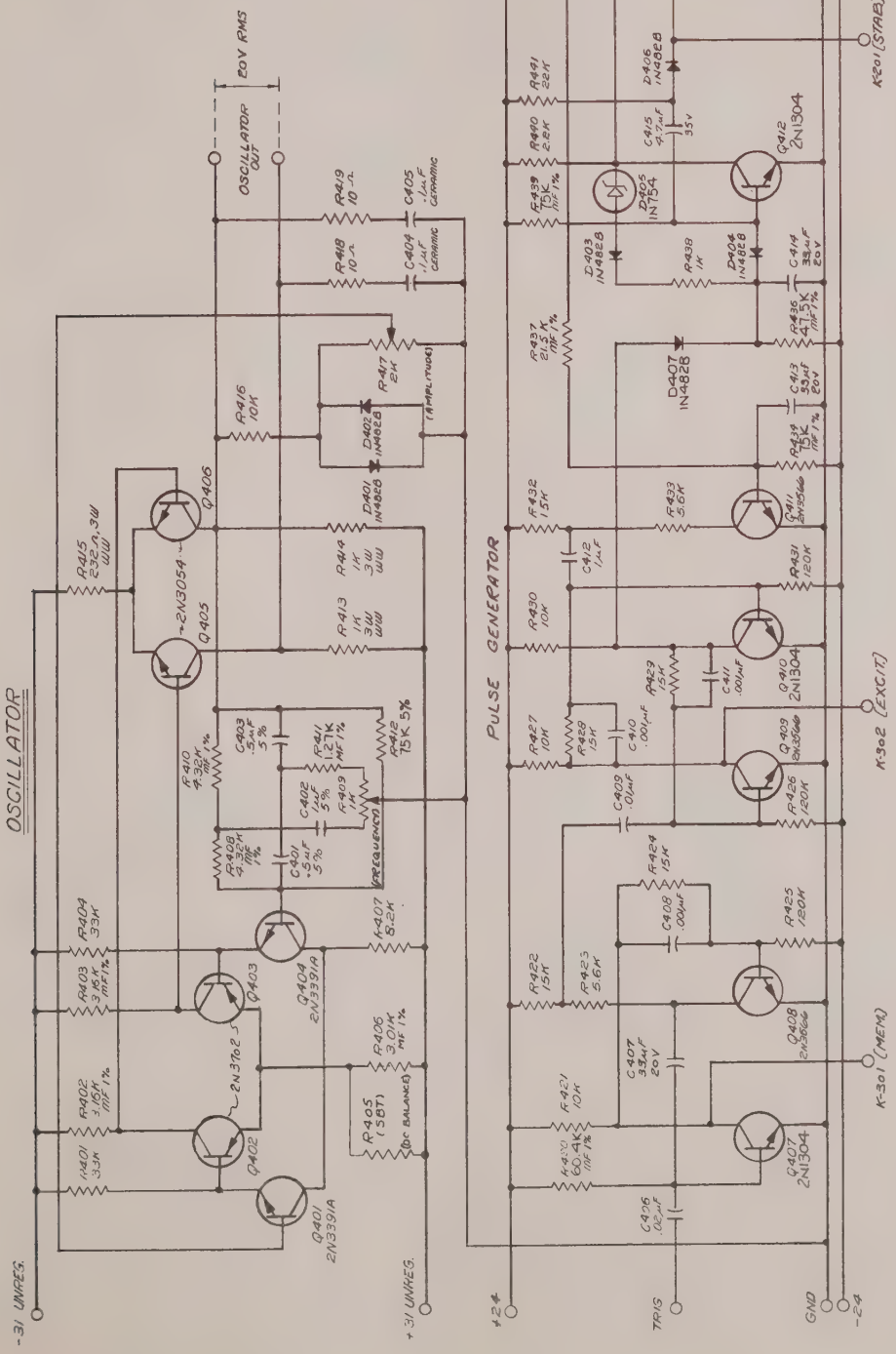
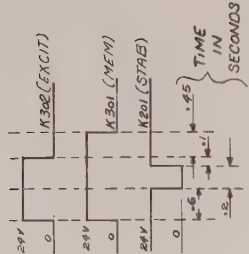
ODDS AND ENDS BOARD

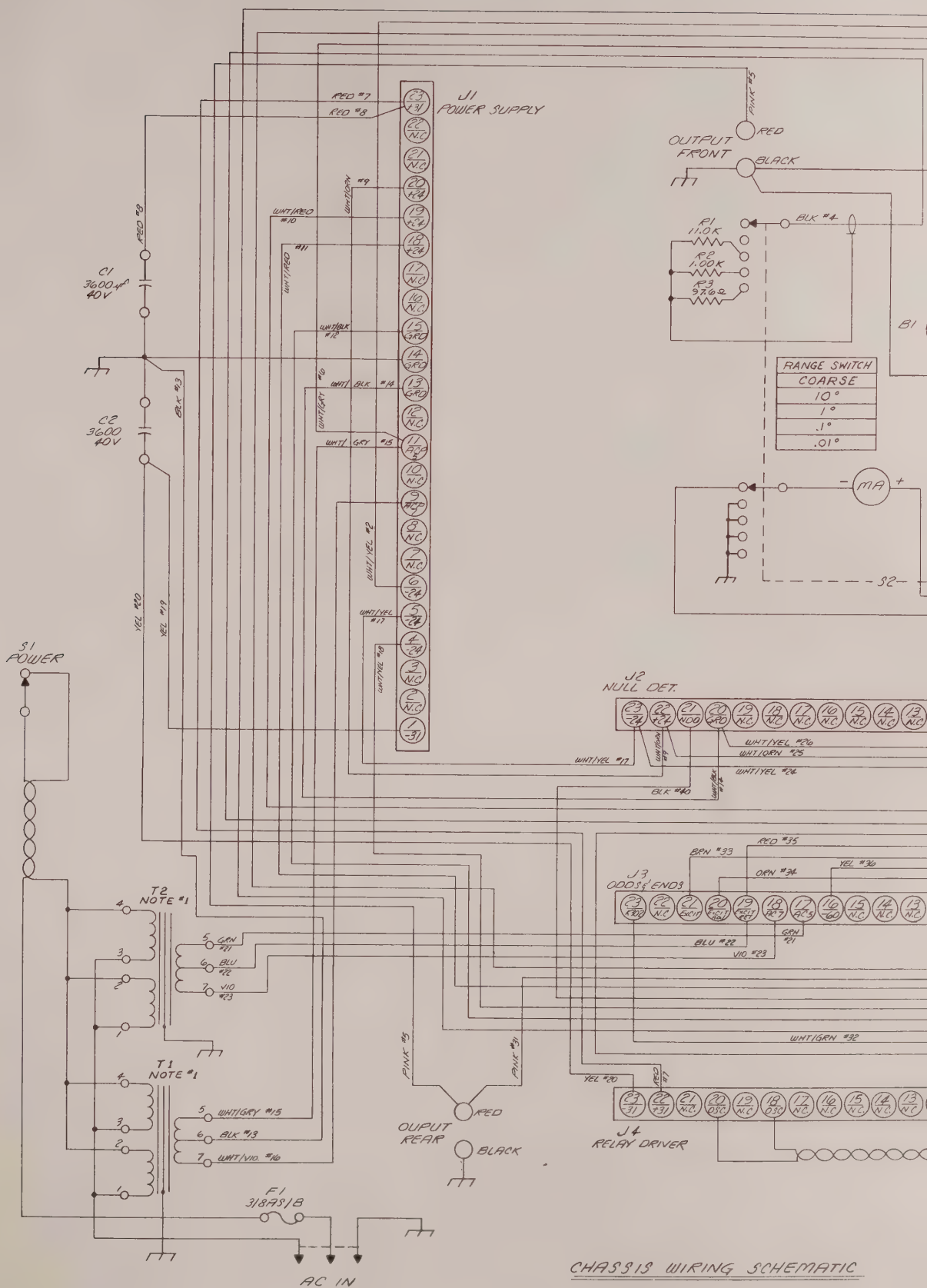
MODEL- PT-2

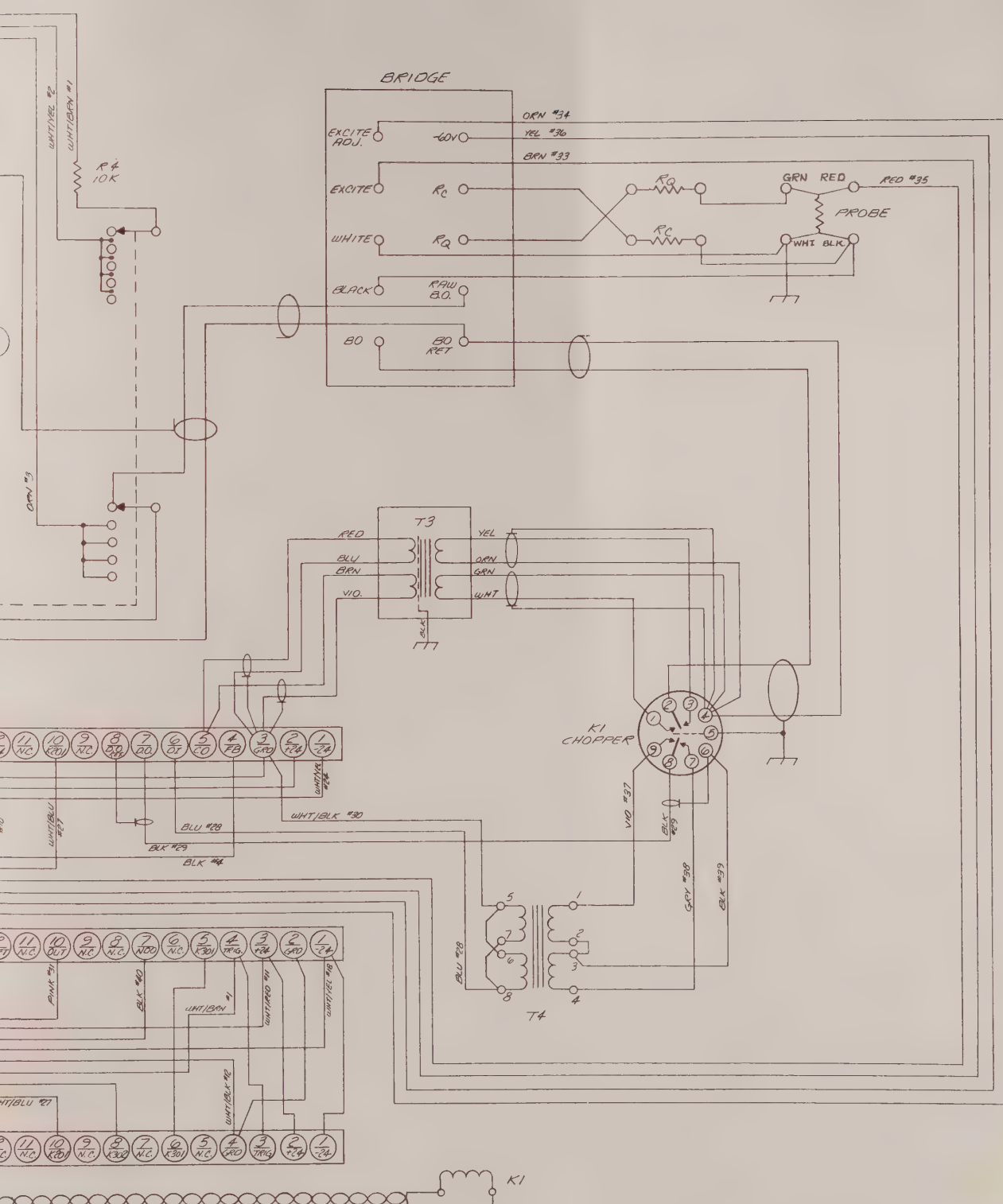
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1-2N3711 TRANSISTOR MAY BE SUBSTITUTED
FOR 2N3391A TRANS.

OUTPUT WAVEFORMS







NOTES:

1- PRIMARY WINDING CONNECTIONS
SHOWN FOR 115V OPERATION.

MODEL PT-2

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SALES OFFICES

Albuquerque

F. Y. Gates Company, Inc.
2631 Texas, N. E.
Albuquerque, N. M. 87110
Tel: (505) 298-1875

Boston

American Dynamics Corp.
17 Dunster Street
Cambridge, Mass. 02138
Tel: (617) 491-6800

Charlotte

Technical Associates, Inc.
3809 Weona Avenue
Charlotte, N. C. 28209
Tel: (704) 523-9121

Chicago

Bard Associates, Inc.
LaGrange Industrial Park
LaGrange, Illinois 60526
Tel: (312) 354-0660

Cleveland

Tiby Company
2245 Warrensville Center Road
Cleveland, Ohio 44118
Tel: (216) 371-5335

Dallas

Noakes Engineering
P.O. Box 967
Irving, Texas 75060
Tel: (214) 255-0441

Dayton

Tiby Company
1954 North Main Street
Dayton, Ohio 45405
Tel: (513) 277-3822

Denver

F. Y. Gates Company, Inc.
3422 South Bannock Street
Englewood, Colorado 80110
Tel: (303) 761-0591

Detroit

Tiby Company
8701 Fenkell Avenue
Detroit, Michigan 48238
Tel: (313) 834-9211

Houston

Noakes Engineering
2128 W. Alabama Street
Houston, Texas
Tel: (713) 529-6213

Huntsville

Technical Associates, Inc.
P.O. Box 1443
Huntsville, Alabama 35800
Tel: (205) 881-8494

Indianapolis

Bard Associates, Inc.
6806 North Farmleigh Drive
Indianapolis, Indiana 46220
Tel: (317) 849-2723

Los Angeles

O'Halloran Associates
10700 Ventura Boulevard
North Hollywood, Cal. 91604
Tel: (213) 877-0173

Minneapolis

Bard Associates, Inc.
7700 Morgan Avenue South
Minneapolis, Minn. 55423
Tel: (612) 866-1700

Montreal

Ahearn & Soper, Ltd.
3300 Cavendish Blvd.
Suite 220
Montreal 28, Quebec
Tel: (514) 482-9750

Orlando

Technical Associates, Inc.
2319 East South Street
Orlando, Florida 32803
Tel: (305) 424-5681

Salt Lake City

F. Y. Gates Company, Inc.
455 East Fourth Street
Suite 311
Salt Lake City, Utah 84111
Tel: (801) 359-1101

San Francisco

O'Halloran Associates
3921 East Bayshore Drive
Palo Alto, Cal. 94303
Tel: (415) 326-1493

Seattle

Avionics Liaison, Inc.
6770 Perimeter Road South
Seattle, Washington 98108
Tel: (206) 723-7602

Toronto

Ahearn & Soper, Ltd.
844 Caledonia Road
Toronto 19, Ontario
Tel: (416) 789-4325

Washington, D. C.

F. R. Jodon, Inc.
4922 St. Elmo Avenue
Bethesda, Maryland 20014
Tel: (301) 652-5110

Export (Europe)

Thomson Electric Company, Inc.
50 Rockefeller Plaza
Room 916
New York, New York 10020
Tel: (212) 245-0444

Export (except Europe)

Henley & Company
202 East 44th Street
New York, New York 10017
Tel: (212) 986-5544

FOREIGN REPRESENTATIVES

Argentina

Coasin S. A.
Virrey Del Pina 4071
Buenos Aires
Tel: 52-3185

Australia

Tecnico Electronics Pty. Ltd.
566 Elizabeth Street
Melbourne
Tel: 34-3694

Austria

International Engineering Service
Etschnerweg 48,
Vienna 14

Brazil

Digimatic Ltd.
P.O. Box 19027
Sao Paulo 15

Denmark

Christian Rovsing Ltd.
51, Rodovrevej
Rodovre
Copenhagen
Tel: (01) 41-10-11

Finland

Havulinna Oy
Vuorikatu 16
P.O. Box 10468
Helsinki 10
Tel: 61451

West Germany

Nucletron Vertriebs GmbH
8 Munich 54
Gaertnerstrasse 60
Tel: (0811) 546081

India

Bali International Agencies, Ltd.
P.O. Box 1676
Bombay 1
Tel: 264592

Israel

Racom Electronics Co., Ltd.
74 Nordau Blvd.
Tel Aviv
Tel: 443244

Italy

Eurelettronica
Milano
Piazza S. Babila, 5
Tel: 799-088

Japan

Rikei Trading Co., Ltd.
Kozato Kaikan Building
No. 18-14 Nishishimbashi
1-Chome Minato-Ku
Tokyo, Japan
Tel: (591) 5246

Netherlands

Nenimij NV
16 Nassau Dillenburgstraat
The Hague
Tel: (070) 244496

New Zealand

AWA (New Zealand) Ltd.
Commercial House
125 Wakefield Street
P.O. Box 830
Wellington, CI
Tel: 43-191

Norway

Hugo Riso
P.O. Box 8 Tassen
Oslo 8
Tel: 23 25 80

South Africa

Electronic Research Labs. Pty. Ltd.
P.O. Box 10523
Johannesburg
Tel: 23-1705

Switzerland

Resistronic AG
Hugistrasse 3
2500 Biel
Tel: 032 356 66

Taiwan

Industrial Electronics, Ltd.
89-2 Lane 75
Nanking East Road
4th Section
Taipei

GENERAL COMPUTATION TABLE

In the following table:

- (a) $1/A_0$ is the initial setting of the $1/A$ control.
- (b) A_0/B_0 is the initial setting of the A/B control.
- (c) R_1 is the dial setting corresponding to balance at reference temperature T_1 .
- (d) R_2 is the dial setting corresponding to balance at reference temperature T_2 .

Record the following.

$1/A_0 =$ _____ $A_0/B_0 =$ _____
 $T_1 =$ _____ $T_2 =$ _____
 $R_2 =$ _____ $R_2 =$ _____

Step #	Compute	Result #	Value
1	$\frac{A_0}{B_0} - R_2$	1	_____
2	#1 (result) $\times T_1$	2	_____
3	#2 $\times R_2$	3	_____
4	#3 $\times T_1$	4	_____
5	$\frac{A_0}{B_0} - R_1$	5	_____
6	#5 $\times T_2$	6	_____
7	#6 $\times R_1$	7	_____
8	#7 $\times T_2$	8	_____
9	#8 - #4	9	_____
10	#7 - #3	10	_____
11	$\frac{\#9}{\#10}$	11	_____ = $\frac{A}{B}$
12	$T_2 - T_1$	12	_____
13	#12 $\times T_2$	13	_____
14	#13 $\times T_1$	14	_____
15	#14 $\times \frac{A_0}{B_0}$	15	_____
16	#15 $\times \frac{1}{A_0}$	16	_____
17	$\frac{\#16}{\#9}$	17	_____ = $\frac{1}{A}$

GENERAL COMPUTATION TABLE

In the following table:

- (a) $1/A_0$ is the initial setting of the $1/A$ control.
- (b) A_0/B_0 is the initial setting of the A/B control.
- (c) R_1 is the dial setting corresponding to balance at reference temperature T_1 .
- (d) R_1 is the dial setting corresponding to balance at reference temperature T_2 .

Record the following.

$1/A_0 =$ _____ $A_0/B_0 =$ _____
 $T_1 =$ _____ $T_2 =$ _____
 $R_2 =$ _____ $R_2 =$ _____

<u>Step #</u>	<u>Compute</u>	<u>Result #</u>	<u>Value</u>
1	$\frac{A_0}{B_0} - R_2$	1	_____
2	#1 (result) $\times T_1$	2	_____
3	#2 $\times R_2$	3	_____
4	#3 $\times T_1$	4	_____
5	$\frac{A_0}{B_0} - R_1$	5	_____
6	#5 $\times T_2$	6	_____
7	#6 $\times R_1$	7	_____
8	#7 $\times T_2$	8	_____
9	#8 - #4	9	_____
10	#7 - #3	10	_____
11	$\frac{\#9}{\#10}$	11	_____ = $\frac{A}{B}$
12	$T_2 - T_1$	12	_____
13	#12 $\times T_2$	13	_____
14	#13 $\times T_1$	14	_____
15	#14 $\times \frac{A_0}{B_0}$	15	_____
16	#15 $\times \frac{1}{A_0}$	16	_____
17	$\frac{\#16}{\#9}$	17	_____ = $\frac{1}{A}$

COMPUTATION TABLE BASED ON THE USE OF
TIN AND ZINC AS REFERENCES

NOTE: The calibration must begin with 1/A set to 251.60 and A/B set to 6700. Also Q and, if necessary, R_Q must be such as to get a balance at 000.00 at the ice point (000.01 at the triple point).

Record the dial settings which give balance at the solidification point of tin and of zinc. In the table these dial settings will be referred to as "TIN" and "ZINC".

TIN _____		ZINC _____	
<u>Step #</u>	<u>Compute</u>	<u>Result #</u>	<u>Value</u>
1 -----	6700.000 - TIN -----	1 -----	<u>6.</u> x 10 ³
2 -----	#1 (result) x TIN -----	2 -----	<u>1.</u> x 10 ⁶
3 -----	#2 x 175,984 -----	3 -----	<u>2.</u> x 10 ¹¹
4 -----	#2 x 419.505 -----	4 -----	<u>6.</u> x 10 ⁸
5 -----	6700.000 - ZINC -----	5 -----	<u>6.</u> x 10 ³
6 -----	#5 x ZINC -----	6 -----	<u>2.</u> x 10 ⁶
7 -----	#6 x 53,783.6 -----	7 -----	<u>1.</u> x 10 ¹¹
8 -----	#6 x 231.913 -----	8 -----	<u>6.</u> x 10 ⁸
9 -----	#3 - #7 -----	9 -----	<u>1.</u> x 10 ¹¹
10 -----	$\frac{3.07652 \times 10^3}{\#9}$ -----	10 -----	<u>2.</u> x 10 ² = $\frac{1}{A}$
11 -----	#4 - #8 -----	11 -----	<u>1.</u> x 10 ⁷
12 -----	$\frac{\#9}{\#11}$ -----	12 -----	<u>6.</u> x 10 ³ = $\frac{A}{B}$

NOTE: To insure accuracy, all numerical values should be carried to at least six significant figures whenever possible.

609-452-2111

PRINCETON APPLIED RESEARCH CORPORATION

P. O. BOX 565, PRINCETON, N. J.

PLATINUM RESISTANCE TEMPERATURE SENSOR

CALIBRATION DATA

Sensor Model No. 1041012Sensor Serial No. 10663 R_Q Trimmer Resistor 99.96 ohms R_Q Trimmer Serial No. 108 R_C Trimmer Resistor 100.55 R_C Trimmer Serial No. 108

PT-2 CALIBRATION DIAL SETTINGS:

 Q 1887.7 $\frac{1}{A}$ 251.715 $\frac{A}{B}$ 6828.5

CALIBRATION CHECK POINTS:

<u>True Temperature</u>	<u>Reading</u>
<u>Ice Point 0.000°C</u>	<u>t.003°C</u>
<u>419.505°C</u>	<u>419.413</u>
<u> </u>	<u> </u>
<u> </u>	<u> </u>

Calibrated By G.P.C.Date 9-30-69

P. O. BOX 565, PRINCETON, N. J.

CALIBRATION DATA

Rc Trimmer Serial No. 108

$\frac{A}{B} = 6724.0$

<u>True Temperature</u>	<u>Reading</u>
<u>Ice Point 0.000°C</u>	<u>+ 0.001°C</u>
<u>Ice Point 231.913°C</u>	<u>231.922°C</u>
<u>Zinc Point 419.505°C</u>	<u>419.478°C</u>

Date April 19, 1967



REFERENCE NO. R195
MODEL NO. PT2
SERIAL NO. 108

CUSTOMER: Magnavox
MODEL EDP NO.
BOARD NO.

CUSTOMER STATEMENT OF PROBLEM:

No statement of problem.

MALFUNCTIONS FOUND:

None, however the probe was recalibrated using tin and zinc solidification points. Final calibration was with zinc point of 419.505°C , which came out to 419.413°C on the instrument.

OTHER DEFECTS FOUND:

None.

COMPONENTS REPLACED OR ADDED:

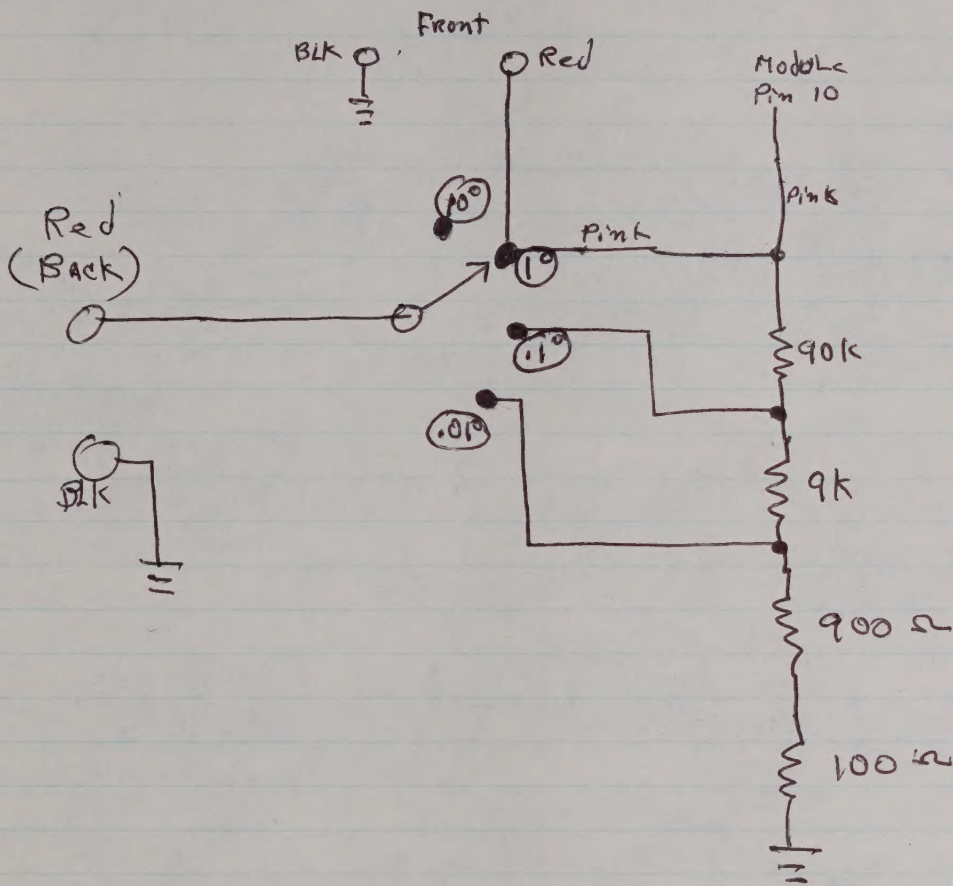
None.

FOR P.A.R. INTERNAL USE ONLY

CUSTOMER PLEASE NOTE: This unit has been retested in accordance with our normal quality assurance test procedures. It meets all of our internal test specifications and is operating normally. It has been completely recalibrated and has undergone an extended stability run.

SIGNED G.P.C. *[Signature]*
F-69-M-5/69-DW

DATE: 10-2-69



15
15

~~555 timer~~

~~555~~

MP MASTER



MA24619